Appl Water Sci (2014) 4:357–362
DOI 10.1007/s13201-013-0151-9

ORIGINAL ARTICLE

Purification of drinking water by low cost method in Ethiopia

Yasabie Abatneh · Omprakash Sahu · Seid Yimer

Received: 23 October 2013 / Accepted: 17 December 2013 / Published online: 5 January 2014

Abstract Nowadays, water treatment is a big issue in rural areas especially in African country. Due to lack of facilities available in those areas and the treatment are expensive. In this regard's an attempt has been made to find alternative natural way to treat the rural drinking water. The experiment trials were undertaken on the most promising plant extracts, namely: *Moringa oleifera*, *Jatropha curcas* and *Guar gum*. The extracts were used to treat contaminated water obtained from a number of wells. The results showed that the addition of *M. oleifera* can considerably improve the quality of drinking water. A 100 % improvement both in turbidity and reduction in *Escherichia coli* was noted for a number of the samples, together with significant improvements in colour.

Keywords Coagulants · *Moringa oleifera* · Plant extracts · Shallow wells

Introduction

Water is a major need on the earth, without it life is impossible. About 1 billion people are without safe drinking water worldwide. The vast majority of these people are located in sub-Saharan Africa, South Asia and East Asia. Countless lives are lost annually due to drinking and using contaminated water (WHO 2006). The people at greatest risk are children, people living under unsanitary conditions and the elderly (WHO 2006). Globally, 4 billion cases of diarrhoea are reported every year causing 1.8 million deaths, out of which about 90 % are children under five (UNESCO 2007). In Ethiopia, the diarrhoea morbidity is around 17 % (Masangwi et al. 2008). The most common source of drinking water for the rural people is groundwater from boreholes (deep wells), shallow wells and springs (Dzwairo et al. 2006). Groundwater is usually consumed without any form of treatment. Water is a medium of thousands of microorganisms some of which are disease-causing. Pathogens (e.g. bacteria, viruses, protozoa and helminths) in water cause a variety of diarrhoea-related diseases such as cholera. These pathogens are commonly derived from human faecal material. Approximately 2.2 billion people are without adequate sanitation in the world. In Ethiopia, the majority of people in rural areas and high density townships in urban areas use pit latrines which are often in a state of disrepair and unhygienic (Lungu et al. 2008). In the rainy season, faecal matter from pit latrines and open sources is washed into water bodies, thereby contaminating the water (Dzwairo et al. 2006). In urban areas, sanitation facilities fill up and overflow if they are not properly managed. Microbiological water quality from shallow wells (with depths not exceeding 20 m), has been found to be more inferior in the wet season compared to the dry season (Pritchard et al. 2007, 2008).

Conventional water purification systems using imported chemicals are prohibitively expensive for developing countries. Ethiopia being a developing country where 52.4 % of people live below the poverty line (World Bank Annual Report, 2013), such expensive conventional methods of assuring potable water quality are unsustainable. In addition to the high cost of importing water treatment, chemicals like aluminium sulphate (Alum), a common coagulant, a number of researchers have also found out that its residue in water may be carcinogenic (Litherland 1995). As a result, people use untreated water from borehole/shallow wells, which pose a threat to their health.

Y. Abatneh · O. Sahu (✉) · S. Yimer
Department of Chemical Engineering, KIOT, Wollo University, Kombolcha, Ethiopia
e-mail: ops0121@gmail.com

Natural plant extracts have been used for water purification for many centuries. Most of these extracts are derived from the seeds, leaves, pieces of bark or sap, roots and fruit extracts of trees and plants (Anwar and Rashid 2007), For example, *Strychnos potatorum* was being used as a clarifier between the fourteenth and fifteenth centuries BC. Shulz and Okun (1984) together with Sanghi et al. (2006) reported that seeds of the nirmali tree (*Strychnos potatorum*) were used to clarify turbid river water 4,000 years ago in India. It is further reported that in Peru, water has been traditionally clarified with the mucilaginous sap of tuna leaves obtained from certain species of cacti. *Zea mays* was used as a settling agent by sailors in the sixteenth and seventeenth centuries.

Natural coagulants have been reported to have several advantages compared to Alum (Aho and Lagasi 2012). Natural coagulants produce much lower sludge volume, the natural alkalinity is not consumed during the treatment process, they are biodegradable, safe to human health, cost effective since they can be locally grown and have a wider effective dosage range for flocculation of various colloidal suspensions (Sanghi et al. 2006). *Moringa oleifera* is medicinal species, belonging to monogeneric family Moringaceae (order Brassicales). It has 33 species of trees and shrubs distributed in sub-Himalayan ranges of India, Sri Lanka, North Eastern and South Western Africa, Madagascar and Arabia (Francis and Liogier 1991; The plant list, 2010). Today, it has become naturalised in many locations of the tropics and is widely cultivated in Africa, Ceylon, Thailand, Burma, Singapore, West Indies, Sri lanka, India, Mexico, Malabar, Malaysia and the Philippines (Fahey 2005).

Bacterial removal in the range of 90–99 % by the powder has also been reported (Madsen et al. 1987). Yongabi (2008) tested the coagulative and disinfective capabilities of *M. oleifera, Jatropha curcas, Pleurotus tuberrregium sclerotium, Hibiscus sabdariffa* and Alum on wastewater samples. *M. oleifera* coagulated about 90 % of the particles in the samples. The coagulation effect was superior in heavily polluted water than less polluted water. The number of coliforms also reduced substantially. It has been also used as water softener (Muyibi and Evison 1995)

The aim of drinking water treatment is to remove impurities and bacteria in order to meet the quality guidelines for drinking water (WHO 2004). *M. oleifera* seeds are recommended for eco-friendly, nontoxic, simplified water treatment where rural and peri-urban people living in extreme poverty (Mangale et al. 2012). Though previous studies reported the use of *M. oleifera* seeds for water purification, (Anwar and Rashid 2007; Broin et al. 2002; Kalogo et al. 2000; Kawo 2007) the seeds under study exhibited resistance to some of the waterborne pathogens (Onsare et al. 2013). In this regards, an effort has been made to establish a database of the naturally occurring coagulant that has been used for water purification and also to carry out preliminary tests on the performance of plant extracts available in Ethiopia on shallow well water.

Materials and methods

Plant extracts

The plant extracts database was produced from literature from different authors. The information on plant extracts included plant names, species, harvesting characteristics, where the plant is cultivated, climatic requirements, uses, estimated cost and other general information were documented.

Preparation of powder and solution

Good quality seeds (not rotten) of *M. oleifera*, *J. curcas* and *Guar gum* were ground using a domestic food processor. The powder was then sieved through a 600 µm sieve. The solution was prepared by dissolving 10 g of powder in 100 ml of distilled water. An appropriate volume of solution was then measured and poured in a 1,000 ml of sample water for the desired concentration.

Sampling

Sampling equipments (filtration unit, forceps, Petri dishes, pipettes and medium) were sterilised using a portable Express Equipment Autoclave Steamer (for 15 min at 116 °C prior to use for microbiological tests). Flaming techniques using tissue paper soaked in 70 % methanol were used to sterilise water discharge points for shallow wells fitted with hand pumps for 60 s (Paqualab Manual 2005; WHO 1997). To eliminate any stagnant water which could have stood in the service pipe, water was pumped to waste for at least 60 s (WHO 1997). Sample bottles were rinsed three times with source water to minimise the risk of external contamination before sampling (Paqualab Manual 2005). For open wells, the sample bottle was held by a metallic bottle holder then plunged into the well to a depth of 0.2–0.3 m below the water level to draw the water sample (WHO 1997; Paqualab Manual 2005). Microbiological analysis was carried out within 3 h after sampling so that the microbiological parameters did not change with time (AWWA 1995). Water samples were collected from five shallow wells from Kombolcha, Dessi, (Kombolcha open well and Dessi) and Chiradzulu (Hrbo, Kemssie and Sorabit). Initial turbidity levels of the well water were taken during sampling. These wells were chosen because of the high average faecal coliform counts from the previous

Table 1 Total and faecal coliform results for studied wells

Well	Total coliforms				Av.	SD	Faecal coliforms				Av.	SD
	Season						Season					
	Dry		Wet				Dry		Wet			
	Aug	Oct	Feb	April			Aug	Oct	Feb	April		
Dessi	2	5625[a]	2,340	500	947	1,232	290	4775[a]	610	30	310	291
Kombolcha	*3,350*	*26,000*	*23,950*	*10,400*	15,925	10,871	*2,600*	*8,700*	*28,450*	*2,000*	10,438	12,384
Kemssie	10	413	[b]	1,685	703	874	0	73	1,218	490	445	559
Hrbo	65	1,350	4,320	5,820	2,889	2,645	35	438	1,015	630	530	408
Sorabit	1,000	2,940	852	875	1,417	1,018	0	60	820	385	316	376

Italics indicate open/unprotected well—all other wells are covered/protected

[a] Well was in state of disrepair (not being used)

[b] Results were nullified

water quality analysis by Pritchard et al. (2007), (2008) as shown in Table 1. Kombolcha open well registered 10,438 faecal coliform counts on average from the previous analyses in 2006 and 2007. Faecal coliform counts for operational covered wells (Dessi, Kemssie, Hrbo and Sorabit) ranged from 0 to 1,218. Samples for this study were collected in January and July, 2012.

Measurement of water quality parameters

Sedimentation jar tests which shown in Fig. 1 were used to determine the coagulation properties of the plant extracts used in this research programme. Five glass beakers of 1,000 ml capacity were filled with raw water obtained for the selected shallow wells. One beaker was used as a control while the other four were dosed, with each plant extract in turn, with concentrations ranging from 50 mg/l to 500 mg/l. Water samples were mixed at a high speed of 200 revolutions per minute for 60 s, as recommended by Peavy et al. (1985). Rapid mixing for a few seconds is important after adding a coagulant to obtain a uniform dispersion of the coagulant and also to increase the opportunity for particle-to-particle contact. Subsequent gentle and prolonged mixing (15 min), which cements the microscopic coagulated particles into larger flocs, followed. The solution was then allowed to stand for 30 min to allow the coagulated particles to settle to the bottom. The supernatant was then filtered on Whatman filter papers no. 542. Turbidity of water was measured using a turbidity metre (ELE: 430-260). Turbidity was measured at extract concentrations ranging from zero (control) to 500 mg/l. Faecal coliforms were only measured at optimum extract concentration to produce minimum turbidity. Faecal coliforms were determined using the membrane filtration technique. A measured volume of water as guided by WHO (2006) was filtered through a membrane. Membranes were

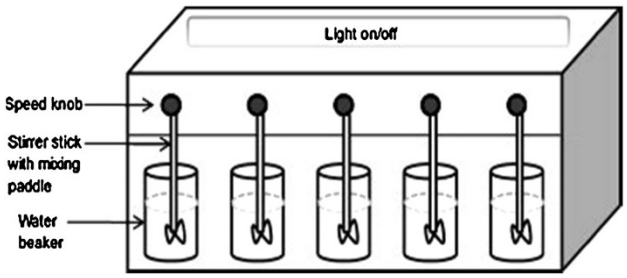

Fig. 1 Jar test equipment

then incubated on Membrane Lauryl Sulphate Broth (MLSB—reference OXOID MM0615) at 44 °C for 24 h. Each test was duplicated and comparable results averaged, essentially to reduce any errors related to measurement. Bacteria that were present on the membranes grew into visible colonies. The viable colonies were counted and converted to represent a count per 100 ml.

Results and discussion

Effect of different extract on sample

The effect of extracts at initial turbidity of 49 NTU with *M. oleifera*, *J. curcas*, *G. gum* are shown in Fig. 2a–e. For water of relatively high initial turbidity, like that of Kombolcha of 49 NTU (Fig. 2a), *M. oleifera* produced the best results with an average percentage in turbidity reduction of 96 %. The optimum dosage for *M. oleifera* was 250 mg/l with a percentage reduction in turbidity of 100 %. *G. gum* was ranked second at an average turbidity percentage reduction of 95 %. The optimum dosage for *G. gum* was 50 mg/l, corresponding to a turbidity reduction of 96 %. *J. curcas* had an average percentage reduction in turbidity of 90 %. The optimum dosage for *J. curcas* was

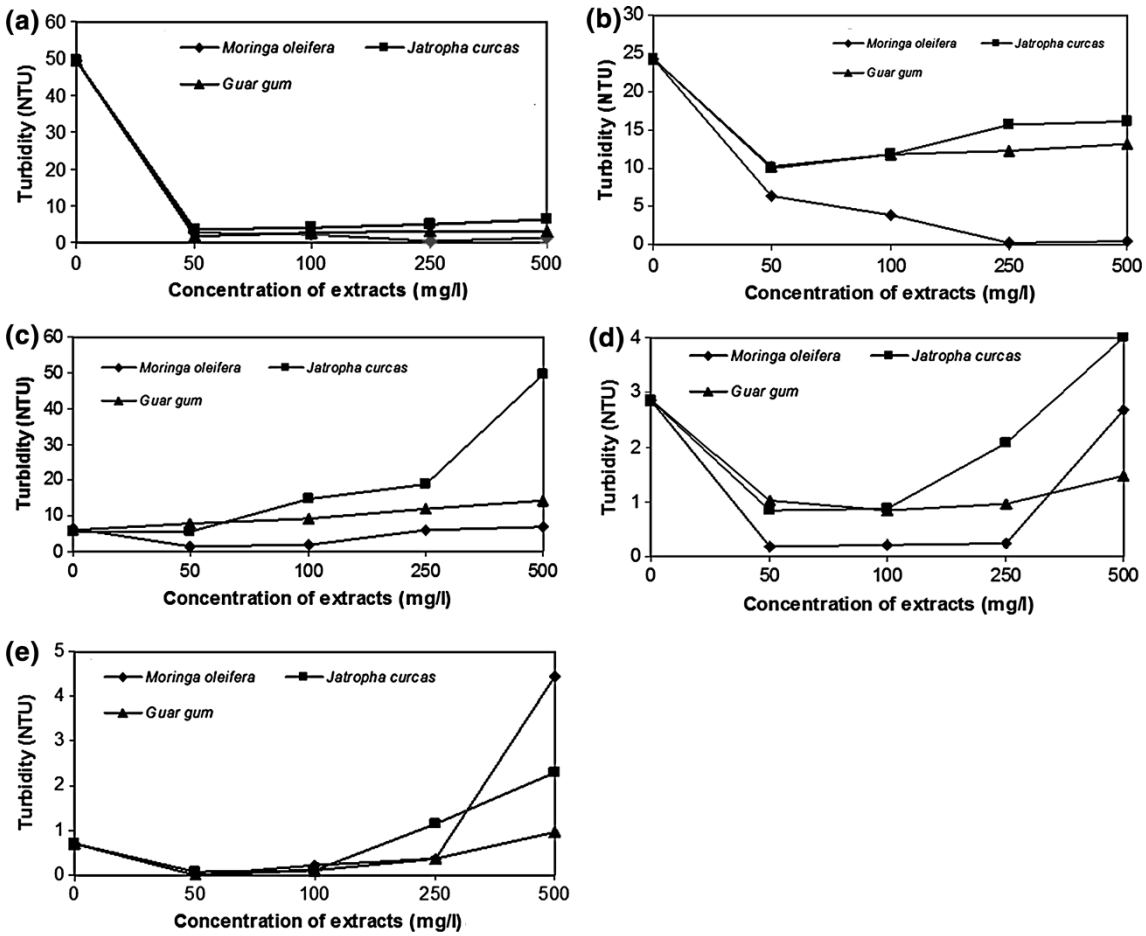

Fig. 2 **a** Effect of MO, JC, and GG on Kombolcha water at To = 49 NTU. **b** Effect of MO, JC, and GG on Sorabit water at To = 49 NTU. **c** Effect of MO, JC, and GG on Hrbo water at To = 49 NTU. **d** Effect of MO, JC, and GG on Kemssie water at To = 49 NTU. **e** Effect of MO, JC, and GG on Dessi water at To = 49 NTU

also 50 mg/l with a turbidity reduction of 92 %. In general, all the extracts (*M. oleifera*, *J. curcas*, and *G. gum*) performed very well in this shallow well water with an average turbidity reduction of 94 %. Sorabit (Fig. 2b) had an initial turbidity of 24 NTU and *Moringa* reduced its turbidity by an average percentage of 89 %. The optimum dosage was 250 mg/l with a turbidity reduction of 99 %. *G. gum* was ranked second with an average turbidity reduction percentage of 52 %, at an optimum dosage of 50 mg/l. Lastly, *J. curcas* reduced the turbidity of this water with an average percentage of 45 %, at an optimum dosage of 50 mg/l.

The worst results were obtained with Hrbo water (Fig. 2c), which had an initial turbidity of 7 NTU for all extracts. The optimum dosage for *M. oleifera* for this water was 100 mg/l with a percentage reduction of turbidity of 75 %. Optimum dosage for *J. curcas* was 50 mg/l, with a percentage reduction of turbidity of 10 %. Turbidity increased at all *G. gum* concentrations. Kemssie (Fig. 2d) had an initial turbidity 3 NTU and *M. oleifera* reduced the turbidity by 93 %, at a concentration of 100 mg/l. At a concentration of 50 mg/l, *J. curcas* reduced the turbidity by 71 %. While the optimum dosage for *G. gum* was 100 mg/l, with a turbidity reduction of 71 %. With water of very low turbidity like that of Dessi (Fig. 2e), which had an initial turbidity of 1 NTU, an optimum dosage of 50 mg/l for all extracts was obtained. *M. oleifera* and *G. gum* produced 100 % turbidity reduction and 88 % for *J. curcas*.

Effect of *Moringa oleifera*

Overall, the *Moringa oleifera* powder produced better results than the other two extracts. To ensure validity of the data, two of the wells (Kemssie and Hrbo) were re-sampled at times of high turbidity (i.e. after period of prolonged rainfall). These results are presented in Fig. 3 and showed that a turbidity reduction in the range of 97–100 % was achieved. In particular, the water from Nluka had an initial turbidity of 219 NTU and looked very turbid together with a brownish colour. At a concentration of 250 mg/l *M. oleifera*, the water was very clear. At

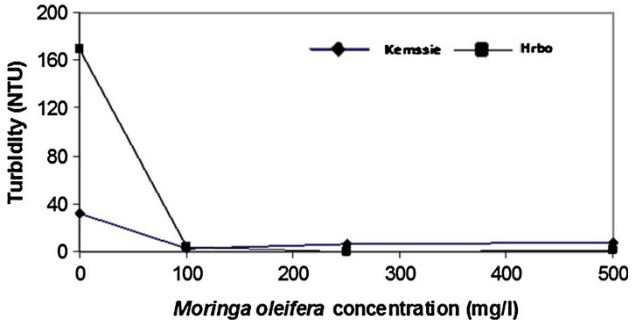

Fig. 3 Effect of MO on Kemssie and Hrbo water at To = 219 NTU

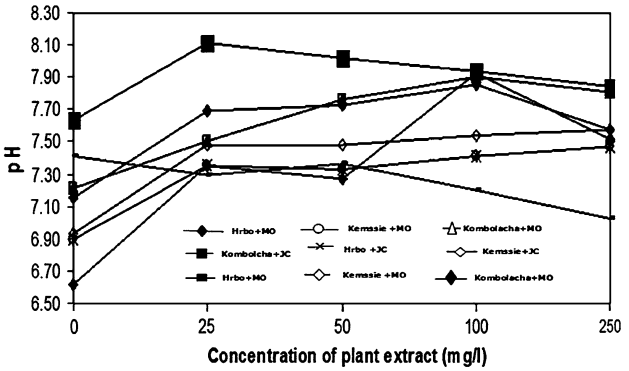

Fig. 4 Effect of MO, JC, and GG on Hrbo, Kemssie and Kombolcha water

higher concentrations + 500 mg/l, the coagulated water had a milky colour. The appropriate concentration ranged from 100 to 250 mg/l. The control had a turbidity reduction of 14 % indicating that just stirring the water, allowing it to settle and then filtering can reduce turbidity of water to a certain extent. Turbidity reduction for Kemssie water which had an initial turbidity of 39 NTU ranged from 72 to 93 %, with an average of 82 %. The reduction of turbidity in the control was 18 %.

It was noted that in 92 % of the samples the pH of the water increased with dose level shown in Fig. 4. This is in agreement with *M. oleifera* results by Ng et al. (2006). It was noted that the pH of water treated by Alum decreased from 6.6 to 5.6 meaning that chemicals needed to be added to raise the pH of water to the required guideline value. An attribute of *G. gum* was that it produced very clear supernatant. Most of the solids accumulated at the bottom of the beakers, even at the highest concentration of 500 mg/l, while suspended solids could be seen with *M. oleifera* and *J. curcas* at concentrations as low as 100 mg/l.

Effect on reduction of coliforms

The reduction in coliforms with different concentrations of *M. oleifera* was also determined. Previously other research

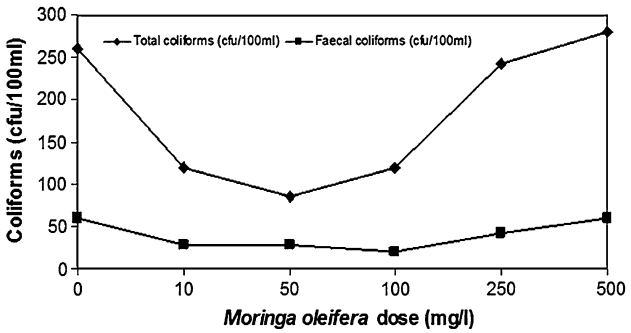

Fig. 5 Effect of MO concentrations on coliforms reduction at 100 mg/l

reported using aqueous and organic extracts of *M. oleifera* Lam (Anith et al. 2011; Sarin et al. 2010). In general, there was a reduction in the number of coliforms and *Escherichia coli* as shown in Fig. 4. The number of total coliforms was reduced from 260 to 86 cfu/100 ml at 50 mg/l. Similarly, the number of *E. coli* was reduced from 60 to 20 cfu/100 ml at 100 mg/l. The antimicrobial properties of the seeds of *M. oleifera* which were found to have inhibitory activity against a number of pathogens (Anwar and Rashid, 2007; Jamil et al. 2007; Kebreab et al. 2005; Lockett et al. 2000) (Fig. 5).

Conclusions

Moringa oleifera, *J. curcas* and *G. gum* reduce turbidity of water. The reduction efficiency is higher for more turbid waters. Turbidity reduction exceeding 90 % was achieved for all the three extracts on shallow well water with an initial turbidity of about 50 NTU. *M. oleifera* exhibited the most favourable results followed by *G. gum* and lastly *J. curcas*. The results indicated that *M. oleifera* can reduce turbidity of shallow well water. *M. oleifera* results for more turbid water (>200 NTU) were better than less turbid water. It was noted that pH of the samples increased as the concentration of the extracts increased. There was, in general, an overall reduction in the number of coliforms and *E. coli* after the water had been treated with *M. oleifera*.

References

Aho IM, Lagasi JE (2012) A new water treatment system using *Moringa oleifera* seed. Am J Sci Ind Res 3(6):487–492

American Water Works Association (AWWA) (1995) Standard methods for the examination of water and wastewater. American Public Health Association Inc., New York

Anith JR, Velliyu KG, Sangilimuthu AY, Sudarsanam D (2011) Antimicrobial activity of *Moringa oleifera* (Lam.) root extract. J Pharm Res 4:1426–1427

Anwar F, Rashid U (2007) Physico-chemical characteristics of *Moringa oleifera* seeds and seed oil from a wild provenance of Pakistan. Pak J Biol Sci 39:1443–1453

Broin M, Santaella C, Cuine S, Kokou K, Peltier G, Joet T (2002) Flocculent activity of a recombinant protein from *Moringa oleifera* Lam. Seeds. Appl Microbiol Biotechnol 60:114–119

Dzwairo B, Hoko Z, Love D, Guzha E (2006) Assessment of the impacts of pit latrines on groundwater quality in rural areas: a case study from Marondera district, Zimbabwe. Phys Chem Earth J 31:779–788

Fahey JW (2005) *Moringa oleifera*: a review of the medicinal evidence for its nutritional, therapeutic and prophylactic properties. Trees life J 1:5

Francis JK, Liogier HA (1991) Naturalized exotic tree species in Puerto Rico. USDA Forest Service General Technical Report SO-82, Southern Forest Experimental Station, (New Orleans, LA, USA), p 12

Jamil A, Shahid M, Khan MM, Ashraf M (2007) Screening of some medicinal plants for isolation of antifungal proteins and peptides. Pak J Bot 39:211–221

Kalogo Y, Rosillon F, Hammer F, Verstraete W (2000) Effect of a water extract of *Moringa oleifera* seeds on the hydrolytic microbial species diversity of a UASB reactor treating domestic wastewater. Lett Appl Microbiol 31:259–264

Kawo AH (2007) Water purification potentials and in vivo toxicity evaluation of the aqueous and petroleum ether extracts of *Calotropis procera*, Latex and *Moringa oleifera* Lam seed powder. PhD thesis, Microbiology Unit, Department of Biological Sciences, Bayero University, Kano

Kebreab AG, Gunaratna KR, Henriksson H, Brumer H, Dalhammar GA (2005) Simple purification and activity assay of the coagulant protein from *Moringa oleifera* seed. Water Res 39:2338–2344

Litherland S (1995) Science: vegetable pods may help solve third world's water woes. Inter Press Service, Washington, DC. Also available at http://treesforlife.org/moringa/uses_water_lgscale_article.htm. Last accessed on 01/06/2004

Lockett CT, Calvet CC, Grivetti LE (2000) Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought: Study of rural Fulani, Northeastern Nigeria. Int J Food Sci Nutr 51:195–208

Lungu K, Morse T, Grimason AM (2008) Ecological sanitation—implementation opportunities and challenges in Chikwawa, Malawi. Environment and Health International. Magazine of the International Federation of Environmental Health, Congress 10(2):1–7

Madsen M, Schlundt J, Omer EFE (1987) Effect of water coagulation by seeds of *Moringa oleifera* on bacterial concentrations. J Tropol Med Hyg 90:101–109

Mangale SM, Chonde SG, Jadhav AS, Raut PD (2012) Study of *Moringa oleifera* (Drumstick) seed as natural absorbent and antimicrobial agent for river water treatment. J Nat Prod Plant Resour 2(1):89–100

Masangwi SJ, Morse T, Ferguson G, Zawdie G, Grimason AM, (2008) A preliminary analysis of the Scotland-Chikwawa health initiative project on morbidity. Environment and Health International. Magazine of the International Federation of Environmental Health, Congress 10(2):10–22

Pritchard M, Mkandawire T, O'Neill JG (2008) Assessment of groundwater quality in shallow wells within the Southern districts of Malawi. Phys Chem Earth J 33:927–935

Muyibi SA, Evison LM (1995) *Moringa oleifera* seeds for softening hard Water. Water Res 29(4):1099–1105

Ng SC, Katayon S, Megat Mohd Noor MJ, Asma M, Abdul Ghani LA, Thamer AM, Azni I, Ahmad J, Khor BC, Suleymen AM (2006) Effects of storage conditions of *Moringa oleifera* seeds on its performance in coagulation. Bioresour Technol 97:1455–1460

Onsare JG, Kaur H, Arora DS (2013) Antimicrobial activity of *Moringa oleifera* from different locations against some human pathogens. Acad J Med Plants 1(5):080–091

Paqualab Manual (2005) Operating instructions. ELE International, 440-005 Issue 1

Peavy HS, Rowe DR, Tchobanoglous G (1985) Environmental engineering. McGraw-Hill Inc, New York

Pritchard M, Mkandawire T, O'Neill JG (2007) Biological, chemical and physical drinking water quality from shallow wells in Malawi: case study of Blantyre, Chiradzulu and Mulanje. Phys Chem Earth J 32:1167–1177

Sanghi R, Bhattacharya B, Dixit A, Singh V (2006) *Ipomoea dasysperma* seed gum: an effective natural coagulant for the decolorization of textile dye solutions. J Environ Manag 81(1):36–41

Sarin R, Manvi M, Sapna B (2010) Evaluation of antibacterial potential of stem bark of *M. oleifera* Lam. Bioscience 1:89–94

Shulz CR, Okun DA (1984) Surface water treatment for communities in developing countries. Wiley, London

The Plant List, Version 1 (2010) Published on the Internet. http://www.theplantlist.org/. Accessed 1st Jan

UNESCO (2007) UNESCO water portal newsletter No. 161: Water-related Diseases. http://www.unesco.org/water/news/newsletter/161.shtml

World Bank (2013) The World Bank Annual Report. http://data.worldbank.org/about/country-classifications

World Health Organisation (WHO) (2006) Guidelines for drinking-water quality, First Addendum to Third Edition, vol 1 Recommendations. Available from: http://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf. Accessed June 2008

World Health Organisation (WHO) (1997) Guidelines for drinking water quality, 2nd edn, vol 3. Surveillance and control of community supplies

World Health Organisation (WHO) (2004) Guidelines for drinking water quality. Volume 1 Recommendations (3rd edn). Geneva, Switzerland

Yongabi KA (2008) Studies on the potential use of medicinal plants and macrofungi (lower plants) in water and wastewater purification. www.biotech.kth.se/iobb/news/kenneth/archive.html. Accessed June 2008